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ATTORNEY DOCKET NO. BOE01 001

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DESIGNATED OFFICE

In re the Application of: Robert Frischholz

International Application No.: PCT/EP9907334

International Filing Date: October 4, 1999

Priority Date Claimed: October 5, 1998

Title: PERSONAL RECOGNITION METHOD AND SYSTEM, INCLUDING MODEL-BASED FINDING

TRANSMITTAL

United States Designated Office
United States Patent and Trademark Office
Box PCT
Washington, D.C. 20231

Sir:

Please commence national stage examination pursuant to 35 U.S.C. 371 for the above-identified PCT patent application.

Enclosed are:

[X] A copy of the international application as filed, including:

[X] Abstract, 8 pages of specification and Claims 1-8.

[X] Two (2) sheets of drawings showing Figures 1-4.

[x] An English Translation of the application as filed, including:

[x] Abstract, 6 pages of specifications and Claims 1-8.

[x] Two (2) sheets of drawings showing Figures 1-4.

[x] An English translation of amended page 2 of the specifications.

[x] An English translation of amended Claims 1-8.

[x] A Preliminary Amendment canceling Claims 3-8 and adding Claims 9-27.

[x] An International Search Report along with an English Translation

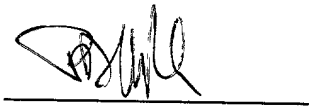
[X] A check in the amount of $ 878.00 to cover the filing fee as calculated below:

NUMBER OF CLAIMS		NUMBER EXTRA		LARGE/SMALL ENTITY	FEE
TOTAL	21 - 20	= 1	x	$18 or $9	= $18.00
INDEP.	1 - 3	= 0	x	$80 or $40	= $0.00
MULTIPLE DEPEND.	[ ] Yes			$270 or $135	= $
For filing with EPO or JPO search report				$860 or $430	= $860.00
If International Preliminary Exam fee paid to USPTO				$690 or $345	= $
If International Preliminary Exam fee paid to USPTO and all USPTO indicates all claims are allowable				$ 100 or $ 50	= $
If International Search fee paid to USPTO, but International Preliminary Exam fee not paid to USPTO				$710 or $355	= $
If neither International Search fee nor International Preliminary Exam fee paid to USPTO				$1,000 or $500	=
				TOTAL FILING FEES	=$878.00

The Commissioner is hereby authorized to charge payment of any additional fees associated with this communication under 37 CFR 1.492 or CFR 1.16 or to credit any overpayment to Deposit Account No. 18-1835.

A duplicate of this sheet is enclosed.

Respectfully submitted,



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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of Robert Frischolz

Serial No.: Unassigned

Filed: Herewith

International Application No.: PCT/EP9907334

International Filing Date: October 4, 1999

Title: PERSONAL RECOGNITION METHOD AND SYSTEM, INCLUDING MODEL-BASED FINDING

PRELIMINARY AMENDMENT

The Honorable Commissioner of
Patent and Trademarks
Washington, D.C. 20231

Sir:

Preliminary to the examination of the subject application, please amend the subject application as follows:

In the Claims:

Please cancel Claims 3-8 without prejudice.

Please add the following new Claims 9-27:

-- 9. (New) The method as claimed in Claim 1, wherein the binarized image first is compared on a small scale with a face model of corresponding small size, the area of the binarized image in which a face was found is enlarged and compared once again with a face model of corresponding larger size, the enlarging and comparing of the binarized

image area and face model are repeated, as the case may be, until the face in the binarized image was localized with sufficient accuracy.

-- 10. (New) The method as claimed in Claim 2, wherein the binarized image first is compared on a small scale with a face model of corresponding small size, the area of the binarized image in which a face was found is enlarged and compared once again with a face model of corresponding larger size, the enlarging and comparing of the binarized image area and face model are repeated, as the case may be, until the face in the binarized image was localized with sufficient accuracy.

-- 11. (New) The method as claimed in Claim 9, wherein different face models with different resolutions are used depending on the size of the binarized image.

-- 12. (New) The method as claimed in Claim 10, wherein different face models with different resolutions are used depending on the size of the binarized image.

-- 13. (New) The method as claimed in Claim 9, wherein the edge extraction for deriving the binarized image from the original image is carried out with different resolutions depending on the size of the binarized image.

-- 14. (New) The method as claimed in Claim 10, wherein the edge extraction for deriving the binarized image from the original image is carried out with different resolutions depending on the size of the binarized image.

-- 15. (New) The method as claimed in Claim 11, wherein the edge extraction for deriving the binarized image from the original image is carried out with different resolutions depending on the size of the binarized image.

-- 16. (New) The method as claimed in Claim 12, wherein the edge extraction for deriving the binarized image from the original image is carried out with different resolutions depending on the size of the binarized image.

-- 17. (New) The method as claimed in Claim 9, wherein the face model and/or the binarized image are rotated and different steps of the rotation are used in depending on the size of the binarized image.

-- 18. (New) The method as claimed in Claim 10, wherein the face model and/or the binarized image are rotated and different steps of the rotation are used in depending on the size of the binarized image.

-- 19. (New) The method as claimed in Claim 11, wherein the face model and/or the binarized image are rotated and different steps of the rotation are used in depending on the size of the binarized image.

-- 20. (New) The method as claimed in Claim 12, wherein the face model and/or the binarized image are rotated and different steps of the rotation are used in depending on the size of the binarized image.

-- 21. (New) The method as claimed in Claim 13, wherein the face model and/or the binarized image are rotated and different steps of the rotation are used in depending on the size of the binarized image.

-- 22. (New) The method as claimed in Claim 14, wherein the face model and/or the binarized image are rotated and different steps of the rotation are used in depending on the size of the binarized image.

-- 23. (New) The method as claimed in Claim 15, wherein the face model and/or the binarized image are rotated and different steps of the rotation are used in depending on the size of the binarized image.

-- 24. (New) The method as claimed in Claim 16, wherein the face model and/or the binarized image are rotated and different steps of the rotation are used in depending on the size of the binarized image.

-- 25. (New) The method as claimed in Claim 1, wherein in the Hausdorff measure is determined on the basis of the average value of a certain percentage of the smallest minimum Hausdorff spacings, the percentage being between 0% and 100 %.

-- 26. (New) A system for implementing the method as claimed in Claim 1, comprising a computing device for calculating the Hausdorff spacing and the Hausdorff measure on the basis of the dots of the binarized image and the face model.

-- 27. (New) A system for implementing the method as claimed in Claim 25, comprising a computing device for calculating the Hausdorff spacing and the Hausdorff measure on the basis of the dots of the binarized image and the face model.

Respectfully submitted,

By: _____

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Dated: April 4, 2001

Personal recognition method and system, including model-based face finding.

The invention relates to a personal recognition method and system, including model-based face finding.

There are methods and systems of biometric personal recognition based on a combination of face recognition, speech recognition, and lip movement recognition. The critical part thereof is the face finding. The invention relates to a method and a system of localizing the face of a person in any camera pictures within such a system of biometric personal recognition.

The fundamental element in face recognition is the face finding, i.e. the precise localizing of the image sector which corresponds to the human face. Some solutions proposed in the prior art simplify these problems by requiring a uniform background in front of which the human face can be found. A face also can be recognized by including moving picture information, it being assumed that the face is contained only in that area of a picture which changes in the course of a picture sequence.

Such simple approaches no longer meet present day requirements of face finding and face recognition. Personal recognition nowadays is assisted, for instance, by PC desk top cameras and other mobile cameras and, therefore, face finding must be robust and work with any kind of background, even with a moving background picture.

The most successful approaches known to date in this field make use of neuron networks. These networks are trained with a great number of examples of faces. In this training an even greater number of "non-face images" are used as a counter-class so that, in the end, the neuron network will be able to distinguish between face and background. It is a disadvantage of this method, apart from the long computing time, that it is highly dependent on variants, like scaling, rotation, and distortion.

It is, therefore, an object of the invention to indicate a novel system and method of face finding which is both robust and able to accomplish the face finding in real time.

This object is met, according to the invention, by a method comprising the features recited in claim 1 and a system comprising the features recited in claim 8.

The method and system according to the invention are model-based. What this means is that a binary image of a human face or a so-called "line drawing" is searched for in a corresponding overall image. Thus an original picture first is converted into a binary image, for instance, by means of edge extraction. This binarized image then is compared with a binary face model to seek and find the image of the human face in the corresponding binarized total image. In contrast to the known approaches, therefore, it is not the intensity value of the individual camera pixels which is compared or pixel variations which are looked for. Rather, the invention relies on a model structure of the type of a line drawing which may be available, for example, in the form of a bit image.

The model of the face or the "line drawing" is compared with the binarized image by means of a modified version of the so-called Hausdorff spacing in numerous scaling, rotation, and distortion variants of the image. The application of the Hausdorff spacing to face recognition was described, e.g. by B. Takacs and H. Wechsler in "Face Recognition Using Binary Image Metrics", 2nd International Conference on Automatic Face and Gesture Recognition, IEFF Proceedings, April 1998. Reference is expressly made to that publication and the explanation it contains of the Hausdorff spacing.

The publication mentioned describes the use of the Hausdorff spacing for purposes of face recognition. It is stated expressly that face finding is achieved by a method which is totally different. It was not taken into consideration in the prior art to apply the Hausdorff spacing for the purpose of face finding, among other things because this algorithm takes an awful lot of calculating time.

The fundamental differences between the problems of face finding and face recognition should be recalled: Once the face is found in a picture, especially in a moving picture this facial picture can be compared with a collection of faces from a data base by almost any method of recognition or identification. If the face in question is contained in the data base the hit rates in general usually are very high, amounting to approximately 99 %. What is difficult with personal recognition, however, is the preceding step, namely first to find the face in any random picture and make a perfect "cutout" thereof. What may appear to be a minor differ-

ence in a literal comparison of face recognition and face finding ultimately is decisive for the quality of the result of facial and, therefore, personal recognition.

Image comparison by resorting to the Hausdorff spacing is based on the following principles:

Two groups of dots are formed of the binarized image and the face model

$$A = \{a_1, \ldots, a_m\}$$

and

$$B = \{b_1, \ldots, b_n\}$$

The Hausdorff spacing then is defined by
H(A,B) = max(h(A,B), h(B,A)
with

$$h(A, B) = \max_{a \in A} \min_{b \in B} \|a - b\|.$$

The system and method according to the invention are not susceptible to the most frequent disturbing effects, such as rotation, different scaling, or distortion of the picture because it is easy to take these into account when comparing the dot groups. Nor is a long learning process needed for application of the method according to the invention, in contrast to the use of neuron networks. Other than with the approaches by way of neuron networks, furthermore, it is not necessary to predetermine, learn, or otherwise allow for any "non-face images". The system recognizes a face like a person does, based on the characteristics of the face itself rather than by relying on background traits which thus need not be taken into consideration. Special characteristics looked for (e.g. a person wearing glasses) quickly can be taken into account in the model by designing the model or "line drawing" accordingly.

In the future, the system and method according to the invention may be used in biometric identification systems for automatic biometric access control with which often facial recognition is combined with speech recognition, lip movement recognition, retina scanning etc.

The invention permits to find the exact face sector, locate the exact eye position for retina scanning, locate the exact mouth position for calculating lip movements, and the like.

But the system and method according to the invention can be applied much more universally too, for instance,ÿby establishing certain binary models so that only persons with certain facial characteristics will be recognized in order to make a distinction according to such aspects as mimics, race, or gender. The method and system according to the invention are not even restricted to face finding because the model for which the search is made also might comprise a hand or another one or more parts of the human body or some matter.

In its preferred embodiments the invention provides for use of a modified Hausdorff spacing to perform the face finding so that the calculating expenditure may be minimized and, therefore, a result be obtained within reasonable computing time. The present embodiment of the modified Hausdorff spacing for face finding permits detection of approximately one face image per second.

In addition, the invention provides a novel preselection of the image by special utilization of the voronoi surface, as further contribution to accelerating the process.

The system and method according to the invention can be realized by software as well as hardware modules, the modified algorithms either being programmed or implemented as separate hardware so that they are real-time suitable, at least in the hardware embodiment.

The invention will be described in greater detail below with reference to the drawings, in which:

Fig. 1 shows an original picture taken with a digital camera;
Fig. 2 shows a binarized version of the original picture of fig. 1;
Fig. 3 shows a binary face model in the form a line drawing; and
Fig. 4 shows the position of the face model found in the binarized image of fig. 2 with the assistance of the face model of fig. 3.

Fig. 1 shows the original picture of a person, including the face, shoulder part, and background. By edge extraction, this picture is converted into the binarized image illustrated in

fig. 2. To accomplish that, the edges at the transitions between bright and dark in the original picture are used to prepare a kind of line drawing of the binarized image as illustrated in fig. 2. What is looked for is the two-dimensional face model of fig. 3, with the aid of the Hausdorff spacing, under the conditions explained in greater detail below.

The general Hausdorff spacing offers a means of determining the similarity of one dot group with another one by examining the proportion of dots in the one group which are located close to dots in the other group, or vice versa. There are two parameters to decide whether the two dot groups are similar or not: (i) the maximum distance by which the dots may be spaced from one another and yet be observed as lying close to one another, and (ii) which is the maximum proportion of dots in one group that has this distance from the dots in the other group.

Face finding by the measure of the Hausdorff spacing differs from other techniques, such as binary correlation, because there is no pairing of dots in the two groups which are compared. An explanation of the mathematical principles of the Hausdorff spacing may be found in the internet under the following address: http://www.cs.cornell.edu/ Vision/hausdorff/hausmatch.html. The principles of the Hausdorff spacing to which reference is made are explained in that document.

The two-dimensional image of the picture presented in fig. 3 thus serves as a face model to be localized in the binarized image of fig. 2, making use of suitable two-dimensional transforms and scalings.

Fig. 4 shows the best conformity of the model of fig. 3 with the binarized image of fig. 2 and, therefore, the position found of the model in the binary image in the sense that in fig. 4 the greatest proportion of binarized edge points of fig. 2 lie in the vicinity of the image dots of fig. 3. When applying the Hausdorff spacing, conformity between the face model and the binarized image is found even if the corresponding binary dots do not coincide precisely.

To practice this model-based face finding method, the following modifications of the Hausdorff spacing are made in a preferred embodiment of the invention in order to achieve face finding in real time:

The invention uses a hierarchic approach with which, to begin with, the binarized image is greatly reduced in size, a correspondingly small face model is searched for in the reduced binarized image; when a specific region is recognized as a likely location of the face looked for then this region and its surroundings are enlarged in order to continue with the search operation based on a model face of corresponding greater size, and so on.

Different models are used in this hierarchic type of search, i.e. with the greatly reduced binarized image, for example, a model (fig. 3) including shoulders is used so that the recognition of the person will be reliable. The greater the scale of the binarized image, the finer the resolution and the more detailed the model will be for the face finding so that, ultimately, a model can be used which includes nothing but eyes, nose, and/or mouth, for example.

The edge extraction for preparing the binarized image of fig. 2 likewise may be adapted to the respective hierarchic levels at which resolutions of different degrees of fineness are required. The invention provides for use of an adaptive Sobel filter to accomplish that.

Respective suitable rotations of the image and/or model may be made within the various hierarchic levels.

Additionally, the invention preferably provides for prefiltering of the binarized image (erosion, dilation, etc.).

The modification of the Hausdorff spacing is another important feature of the invention. An especially preferred embodiment of the invention provides for working with a modified Hausdorff spacing in which not only the average distance of all the minimum distances between the model and the image is utilized as the measure of the spacing. Instead, the average value of the first x % ($0<x<100$) of all the minimum distances serves as the basis for calculating the Hausdorff measure so that larger deviations ("escapes") will not be taken into account and falsify the result.

Claims

1. A method of finding a face in a binarized image by comparing the dot group of the binarized image with the dot group of a face model, wherein the dot groups of the binarizedÿimage and of the face model are compared on the basis of the Hausdorff spacing between the dots of the dot groups, and a face in the binarized image is recognized when a measure derived from the Hausdorff spacing fails to reach a limit value.

2. The method as claimed in claim 1, wherein the binarized image is derived from the original image by means of edge extraction.

3. The method as claimed in claim 1 or 2, wherein the binarized image first is compared on a small scale with a face model of corresponding small size, the area of the binarized image in which a face was found is enlarged and compared once again with a face model of corresponding larger size, the enlarging and comparing of the binarized image area and face model are repeated, as the case may be, until the face in the binazired image was localized with sufficient accuracy.

4. The method as claimed in claim 3, wherein different face models with different resolutions are used depending on the size of the binarized image.

5. The method as claimed in claim 3 or 4, wherein the edge extraction for deriving the binarized image from the original image is carried out with different resolutions depending on the size of the binarized image.

6. The method as claimed in any one of claims 3 to 5, wherein different steps of rotation are used depending on the size of the binarized image.

7. The method as claimed in any one of the preceding claims, wherein the Hausdorff measure is determined on the basis of the average value of the smallest x % of all minimum Hausdorff spacings, with $0<x<100$.

8. A system for implementing the method as claimed in any one of the preceding claims, comprising a computing device for calculating the Hausdorff spacing and the Hausdorff measure on the basis of the dots of the binarized image and the face model.

Abstract of the Disclosure

Personal recognition method and system,
including model-based face finding.

The invention relates to a face finding method and system in a binarized image by comparing the dot group of the binarized image with the dot group of a face model, wherein the dot groups of the binarized image and of the face model are compared on the basis of the Hausdorff spacing between the dots of the dot groups and a face is recognized in the binarized image when a measure derived from the Hausdorff spacing fails to reach a limit value.

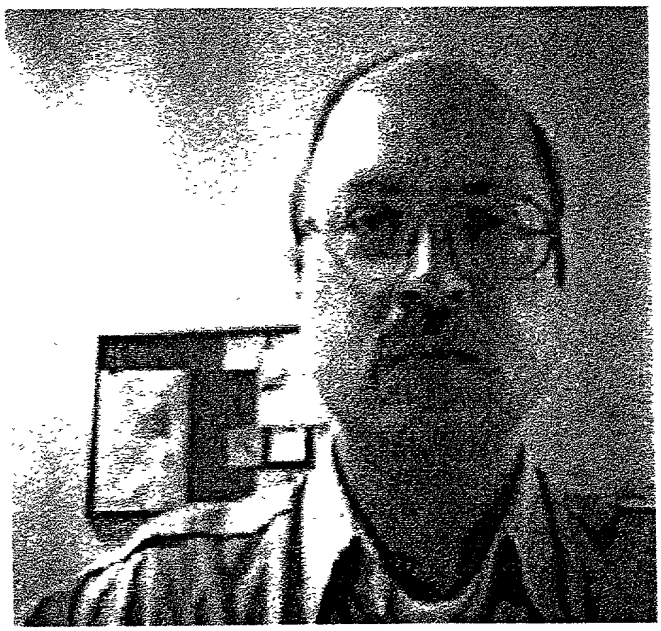

Fig. 1

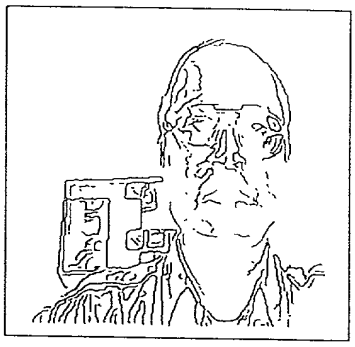

Fig. 2

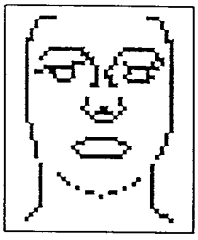

Fig. 3

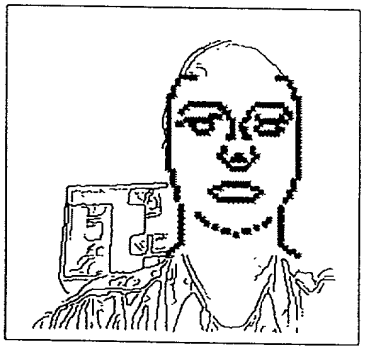

Fig. 4

This object is met, according to the invention, by a method comprising the features recited in claim 1 and a system comprising the features recited in claim 8.

The method and system according to the invention are model-based. What this means is that a binary image of a human face or a so-called "line drawing" is searched for in a corresponding overall image. Thus an original picture first is converted into a binary image, for instance, by means of edge extraction. This binarized image then is compared with a binary face model to seek and find the image of the human face in the corresponding binarized total image. In contrast to the known approaches, therefore, it is not the intensity value of the individual camera pixels which is compared or pixel variations which are looked for. Rather, the invention relies on a model structure of the type of a line drawing which may be available, for example, in the form of a bit image.

The model of the face or the "line drawing" is compared with the binarized image by means of a modified version of the so-called Hausdorff spacing in numerous scaling, rotation, and distortion variants of the image. The application of the Hausdorff spacing to face recognition was described, e.g. by B. Takacs and H. Wechsler in "Face Recognition Using Binary Image Metrics", **3rd** International Conference on Automatic Face and Gesture Recognition, **IEEE** Proceedings, April 1998. Reference is expressly made to that publication and the explanation it contains of the Hausdorff spacing.

The publication mentioned describes the use of the Hausdorff spacing for purposes of face recognition. It is stated expressly that face finding is achieved by a method which is totally different. It was not taken into consideration in the prior art to apply the Hausdorff spacing for the purpose of face finding, among other things because this algorithm takes an awful lot of calculating time.

The fundamental differences between the problems of face finding and face recognition should be recalled: Once the face is found in a picture, especially in a moving picture this facial picture can be compared with a collection of faces from a data base by almost any method of recognition or identification. If the face in question is contained in the data base the hit rates in general usually are very high, amounting to approximately 99 %. What is difficult with personal recognition, however, is the preceding step, namely first to find the face in any random picture and make a perfect "cutout" thereof. What may appear to be a minor differ-

(Amended) C l a i m s

1. A method of finding a face in a binarized image by comparing the dot group of the binarized image with the dot group of a face model, the face model being subjected to multiple two-dimensional transforms in order to locate the face model in the binarized image, and the dot groups of the binarizedÿimage and of the face model being compared on the basis of the Hausdorff spacing between the dots of the dot groups and a position of a face in the binarized image is found when a measure derived from the Hausdorff spacing fails to reach a limit value.

2. The method as claimed in claim 1, wherein the binarized image is derived from the original image by means of edge extraction.

3. The method as claimed in claim 1 or 2, wherein the binarized image first is compared on a small scale with a face model of corresponding small size, the area of the binarized image in which a face was found is enlarged and compared once again with a face model of corresponding larger size, the enlarging and comparing of the binarized image area and face model are repeated, as the case may be, until the face in the binazired image was localized with sufficient accuracy.

4. The method as claimed in claim 3, wherein different face models with different resolutions are used depending on the size of the binarized image.

5. The method as claimed in claim 3 or 4, wherein the edge extraction for deriving the binarized image from the original image is carried out with different resolutions depending on the size of the binarized image.

6. The method as claimed in any one of claims 3 to 5, wherein the face model and/or the binarized image are rotated and different steps of rotation are used depending on the size of the binarized image.

7. The method as claimed in any one of the preceding claims, wherein the Hausdorff measure is determined on the basis of the average value of a certain percentage of the smallest minimum Hausdorff spacings, the percentage being between 0 % and 100 %.

8. A system for implementing the method as claimed in any one of the preceding claims, comprising a computing device for calculating the Hausdorff spacing and the Hausdorff measure on the basis of the dots of the binarized image and the face model.

MAY 2001

ATTORNEY DOCKET NO. BOE01 001

COMBINED DECLARATION AND POWER OF ATTORNEY FOR UTILITY PATENT APPLICATION

As a below named inventor, I hereby declare:

that my residence, post office address and citizenship are as stated below next to my name;

that I verily believe that I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the invention which is the subject of an application entitled: PERSONAL RECOGNITION METHOD AND SYSTEM, INCLUDING MODEL-BASED FINDING; said invention being described and claimed [ ] in the attached specification [X] in the specification of application Serial No. 09/806,785, filed April 4, 2001; that I have reviewed and understand the content of said specification including the claims; that I do not know and do not believe the said invention was ever known or used in the United States before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to said application; that said invention was not in public use or on sale in the United States more than one year prior to said application; that said invention has not been patented or made the subject of an inventor's certificate issued before the date of said application in any country foreign to the United States on an application filed by me or my legal representatives or assigns more than twelve months prior to said application; that I acknowledge my duty to disclose information of which I am aware which is material to patentability as defined in 37 CFR 1.56; and that no application for patent or inventor's certificate on this invention has been filed in any country foreign to the United States prior to said application by me or my legal representatives or assigns, except as follows:

COUNTRY/INTERNATIONAL	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 U.S.C. 119/365
			YES X NO
GERMANY	19847261.7	5 OCTOBER 1998	
			YES NO

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application listed below:
U.S. Provisional Application S.N. _____ filed _____.

I hereby appoint L. Lawton Rogers, III, Reg. No. 24,302; D. Joseph English, Reg. No. 42,514; Mark C. Comtois, Reg. No. 46,285; and Patrick D. McPherson, Reg. No. 46,255 to prosecute said application and to transact all business in the Patent and Trademark Office connected therewith and to file, prosecute and transact all business in connection with international applications directed to said invention:

Address all correspondence to: Carter, Ledyard & Milburn
1401 Eye Street, N.W., Suite 300
Washington, DC 20005

Address all telephone calls to (202) 898-1515

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Robert Frischholz — x [signature] — 4.5.2001
FULL NAME OF SOLE OR FIRST INVENTOR — SIGNATURE — DATE

HERDEGENWEG 9 90427 NÜRNBERG — Germany
RESIDENCE — CITIZENSHIP

c/o DCS Dialog Communication Systems AG Am Wetterkreuz 19a 91058 Erlangen, GERMANY — DEX
POST OFFICE ADDRESS